

Long Term Corrosion/Degradation Test Third-Year Results

1. INTRODUCTION

1.1 Purpose

The Long Term Corrosion/Degradation (LTCD) test project, described in this report, is designed to support the determination of site-specific corrosion rates for metals representing the neutron-activated metals buried at the Subsurface Disposal Area (SDA) at the Idaho National Engineering and Environmental Laboratory (INEEL). Corrosion rates will be based on measurements of metal loss (i.e., the resulting metal wastage or thinning of specimens) from metal coupons and electrical resistance (E/R) probes exposed to SDA conditions. The corrosion rates, thus determined, will be applied to the modeling of the transfer of activated elements from the buried metals to the surrounding environment. The test results will provide site-specific data to satisfy programmatic needs, including radiological fate and transport modeling that will contribute to ongoing radiological composite analyses, performance assessments, and the environmental baseline risk assessments conducted for the SDA.

1.2 Scope

This report documents the current status of the LTCD test project, presents the results of the 3-year retrieval, and evaluates and compares the 3-year results with the 1-year results. Tentative conclusions are presented with recommendations for the future conduct of the test.

1.3 Objectives

The LTCD test project is designed to determine the corrosion rates of neutron-irradiated metallic materials buried at the SDA. The corrosion rate data are needed to support a more accurate estimate of the site-specific transfer of radioactive isotopes to the environment (radiological release rates). Of interest are the metallic materials used to fabricate nuclear reactor components that were exposed to high neutron fluxes in a reactor environment, such that they became activated with long-lived radioactive isotopes. After disposal of the irradiated metallic waste at the SDA, corrosion processes can cause these radioactive isotopes to be released to the environment. The current SDA Performance Assessment (Case et al. 2000; Maheras et al. 1994) and Composite Analysis (McCarthy et al. 2000) postulate that the largest contributor to the future public dose will be C-14, which is released as the metal corrodes. With the corrosion rates used by those documents, the predicted dose from C-14 is high enough to trigger the need for a formal options analysis to supplement the composite analysis. One option is to continue testing to demonstrate that the corrosion rates are lower than assumed, which would result in lower doses being predicted for C-14.

The LTCD test location provides an underground environment similar to that in which the neutron-activated metals are buried at the SDA. Corrosion rates will be established for nonradioactive metals representing the prominent activated metals buried at the SDA. The project's use of nonradioactive metal coupons, as well as probes equipped with nonradioactive metal strips, assumes that activation does not affect corrosion characteristics or corrosion mechanisms.

Environmental conditions existing or potentially existing at the SDA affect the corrosion rates of metals buried there. Underground corrosion rates are directly related to soil characteristics. Testing of corrosion-related environmental conditions will be performed throughout the test duration, including

characterization of soil used at the test location (from Spreading Area B) with analysis for chemical, physical, hydraulic, and microbiological characteristics, along with characterization of soil at the SDA for comparison purposes. Precipitation, soil moisture and other conditions will be monitored. Some of the corrosion probes will be exposed to moisture in excess of natural precipitation with the intent to evaluate the effect of supplemental moisture on the corrosion rate. An isolated area of the test location is reserved for investigation of other possible environmental effects that are related directly to specific SDA conditions. Use of the isolated area will depend on funding availability and research needs.

1.4 Background

The SDA, which is part of the Radioactive Waste Management Complex (RWMC) at the INEEL, has been a major disposal site for solid radioactive waste since the early 1950s. The SDA contains low-level waste, transuranic waste, hazardous waste, and mixed waste. Since 1970, incoming waste generally has been segregated according to waste type before disposal, and transuranic waste has been stored instead of being placed in disposal. A large portion of the radioactive content of the waste disposed at the SDA consists of neutron-irradiated metals, mostly reactor core structural components (i.e., subassemblies, cladding, and other non-fuel reactor core components) composed of stainless steel, nickel-based alloys (such as Inconel 718), and other metals.

The large amount of neutron-irradiated metal buried at the SDA represents an environmental concern. The irradiation produces long-lived (C-14, Ni-59, Nb-94, Tc-99) and short-lived (Co-60, Ni-63) radioactive isotopes (10 CFR 61). In addition, a possible short-term release rate component is the tritium that is formed under neutron irradiation of beryllium. The radioactive isotopes are contained inside the crystalline structure of the metal, and the assumption is that most of the isotopes release into the environment only through metallic corrosion (Rood and Adler-Flitton 1997). Thus, for these isotopes, the calculated radiological release rates are driven by the assumed corrosion rates.

Department of Energy (DOE) Order 435.1, "Radioactive Waste Management," requires a radiological composite analysis and a performance assessment of existing and proposed DOE low-level waste facilities. In the original performance assessment for the SDA (Maheras et al. 1994), release rates for a variety of reactor components were obtained using the IMPACTS methodology (Oztunali and Roles 1986) and were based on corrosion rates of 4 mils per year (MPY) (1.02×10^{-4} m/year) for carbon steel and 0.3 MPY (7.62×10^{-6} m/year) for stainless steel. The corrosion rates for the stainless steel are rates from the IMPACTS study for austenitic stainless steels (Types 304 and 316) in natural waters and seawater.

The rates at which the irradiated metals buried at the SDA actually corrode might be different than the "textbook" corrosion rates assumed in the SDA performance assessment and composite analysis. For example, a recent study reviewed corrosion rates for low carbon steels, Types 304 and 316 stainless steels, and Inconel 600, 601, and 718 alloys in SDA-type soils (Nagata and Banaee 1996). That study estimated that the corrosion rate for the stainless steels and the Inconel 718 in environments with geochemistry similar to that of the SDA soils was 0.00047 MPY (1.2×10^{-8} m/year), which is about three orders of magnitude lower than the corrosion rate assumed for stainless steel in the original Maheras et al. (1994) SDA performance assessment.

The current SDA Composite Analysis (McCarthy et al. 2000) and the supplementary update for the SDA Performance Assessment (Case et al. 2000) use the Disposal Unit Source Term—Multiple Species (DUST-MS) software to model the container failures and release mechanisms. Corrosion rate data entered into the model were 2.2×10^{-7} MPY (Nagata 1997) for stainless steels and 2.2×10^{-6} to 1.5×10^{-6} MPY (Nagata and Banaee 1996) for carbon steels. The corrosion rates cited in the literature and used as the basis for the radiological release rate estimates are typically derived from testing in water or in soils that

are wetter and less alkaline than SDA soils. As the need for more accurate release rate estimates increases, the importance of the site-specific corrosion rate information being generated by the LTCD testing becomes greater.

1.5 Test Strategy

The LTCD test project consists of four main components:

- Direct corrosion testing, using metal coupons buried in the soil
- Monitored corrosion testing, using electrical resistance probes equipped with thin metal strips
- Soil characterization, sampling, and analysis for physical, chemical, hydraulic, and microbiological properties
- Monitoring of field conditions, including precipitation, soil moisture, soil-water chemistry, soil-gas composition, and soil temperature.

The direct corrosion testing and the monitored testing provide corrosion rate data. The soil characterization and field monitoring aid in the evaluation and comparison of the corrosion results.

Direct corrosion testing using direct buried coupons is the most widely used and simplest method of underground corrosion testing. Specially prepared metal coupons of known compositions are measured for dimension and weight before being buried. This measurement is taken so that corrosion rates can be determined by measuring the resulting coupon weight loss upon coupon recovery and cleaning after a known time period. Corrosion times will range from one to as many as 32 years.

The monitored testing uses E/R probes. The E/R technique is an online method of measuring the extent of total metal loss, based on the electrical resistance of a metallic strip subjected to corrosion conditions, compared to that of a strip protected from corrosion. The electrical resistance of metals changes as corrosion occurs, allowing determination of the corrosion rate.

Both the buried coupon method and the E/R method are industry-standard methods for measuring corrosion. The corrosion tests (both methods) are being conducted in soil brought to the test location from Spreading Area B, the primary source of the soil used as backfill to cover the waste buried at the SDA.

The LTCD test project began in 1997 with burial of metal coupons for direct testing. Additional coupons were buried in 1998 and 2000. The direct testing will continue, as funding permits, until about 2030 or until enough data have been collected to satisfy the input requirements for the models used in the radiological composite analyses, performance assessments, and environmental baseline risk assessments for the SDA. Mizia et al. (2000) reported the results when 1-year coupons (coupons exposed to one year of corrosion) were removed and examined in 1998. Monitored testing began in 2000 when E/R probes were installed and will continue, funding permitting, until the end of the test period or until the probes fail. The timing and extent of soil characterization work depends on funding availability and research needs. Field conditions will be monitored during the entire test period. Schedule details are provided later in this report.

The direct testing is using nonradioactive coupons of various metals and alloys selected to generally represent the irradiated metals buried at the SDA. The materials included in the direct testing are Type 304L stainless steel, Type 316L stainless steel, welded Type 316L stainless steel, Inconel 718, Beryllium S200F, Aluminum 6061, and Zircaloy-4 (the list recommended by Rood and

Adler-Flitton [1997]). In addition, low-carbon steel (the material presently used in the disposal liners of the 55-ton scrap casks and other disposal liners and containers) and Ferralium 255 (a proposed material for construction of high-integrity disposal containers) are included as part of the test. The monitored testing is using E/R probes equipped with metal strips of the following materials: Type 304L stainless steel, Type 316L stainless steel, Inconel 718, Aluminum 6061, Zircaloy-4, and low-carbon steel.

1.6 Test Location

The LTCD test location is near the SDA. The corrosion coupons and E/R probes buried at the test location are exposed to the same soil and environmental conditions as the activated metals buried in the SDA, but the test location is not inside the SDA boundaries. The LTCD tests are being conducted at a specially constructed test site adjacent to the Engineered Barriers Test Facility (EBTF) located about 900 ft north of the SDA, as shown in Figure 1.

Direct burial in the SDA was not feasible for the following reasons:

- The SDA has limited access because of radiological concerns
- Limited space is available in the SDA for coupon emplacement
- The logistics of handling samples with possible radiological contamination are too complex
- The final soil cover might be placed on the SDA before the end of the project.

The EBTF (see Figure 2) was constructed to test the hydraulic performance of prospective engineered barriers for use at the SDA. The berm on the east side of the EBTF was expanded to form the Engineered Barriers Extension (EBE), where the LTCD test is being conducted (see Figure 3). Native soil underlying the EBE area was excavated to a depth of 2 ft, and soil from Spreading Area B was brought in to form a rectangular berm to replicate soil conditions in the SDA where the activated metals are buried. The EBE, which is 10 ft high (above the existing grade), has sloping sides and a flat top. The top surface dimensions are 85 ft east to west and 88 ft north to south (see Figure 3). The test location includes construction of a cone-shaped, flat-topped mound, the Northern Isolation Mound (NIM), where testing for specific environmental effects might be conducted. For convenience and brevity, this report refers to the EBE as the berm, and to the NIM as the mound.

The *Long Term Corrosion/Degradation Test*, Test Plan (Adler-Flitton et al. 2001) calls for burial of coupons and/or probes at as many as 10 designated locations in the berm, as shown in Figure 4. Each set of 36 coupons, after assembly, is referred to in this report as a coupon array. Each set of six probes and associated instrumentation is referred to as a probe array. In general, two sets of coupons or probes will be buried at each location, one set at 4 ft and one set at 10 ft. In some instances, a probe array and a coupon array might be buried at the same location at the same depth. Some of the locations can be used more than once; for example, if two coupon arrays are removed for evaluation after only a year or a few years, new arrays can be installed at that location as part of the ongoing test.

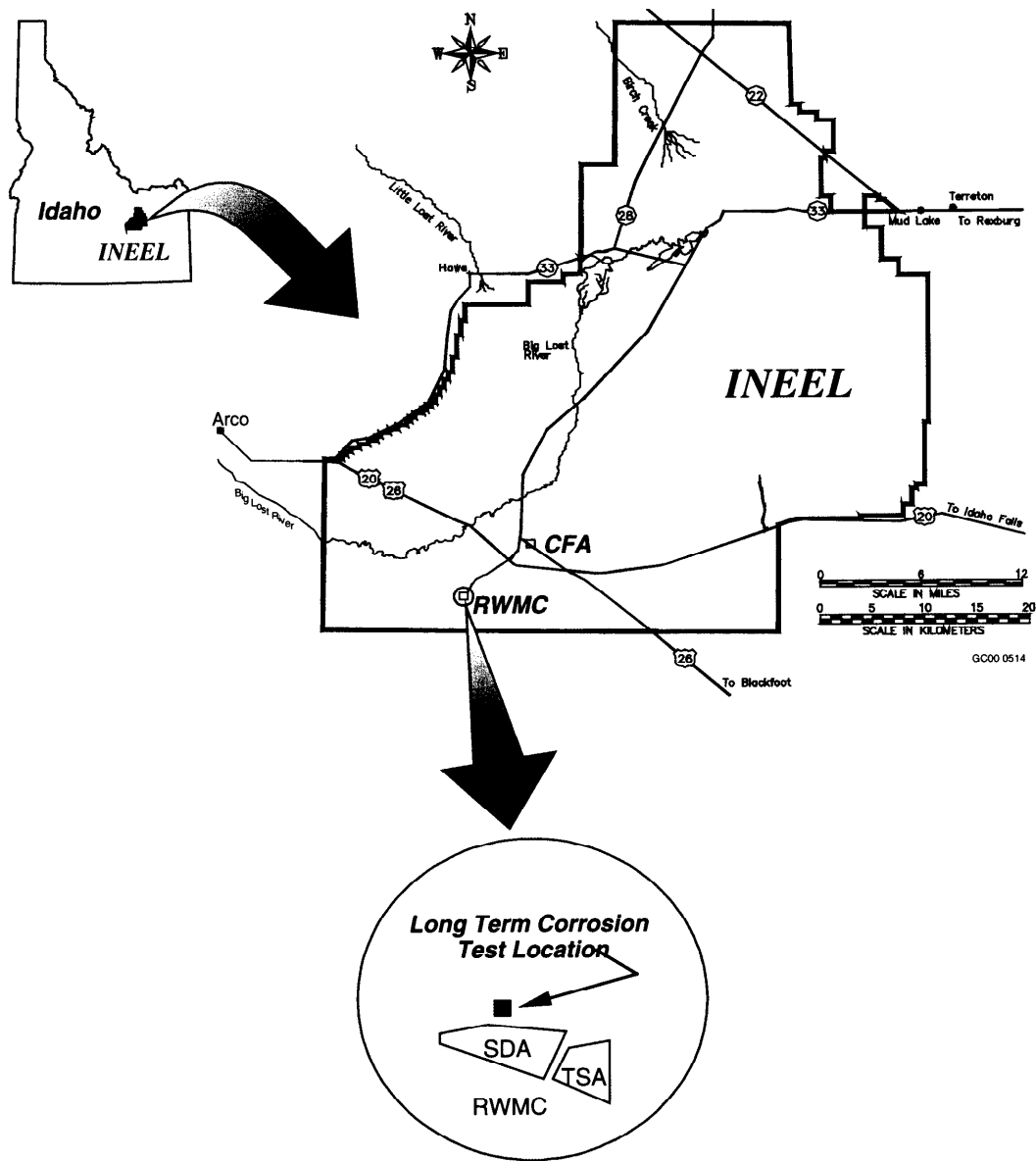


Figure 1. Location of the long term corrosion/degradation testing near the Radioactive Waste Management Complex Subsurface Disposal Area at the Idaho National Engineering and Environmental Laboratory.

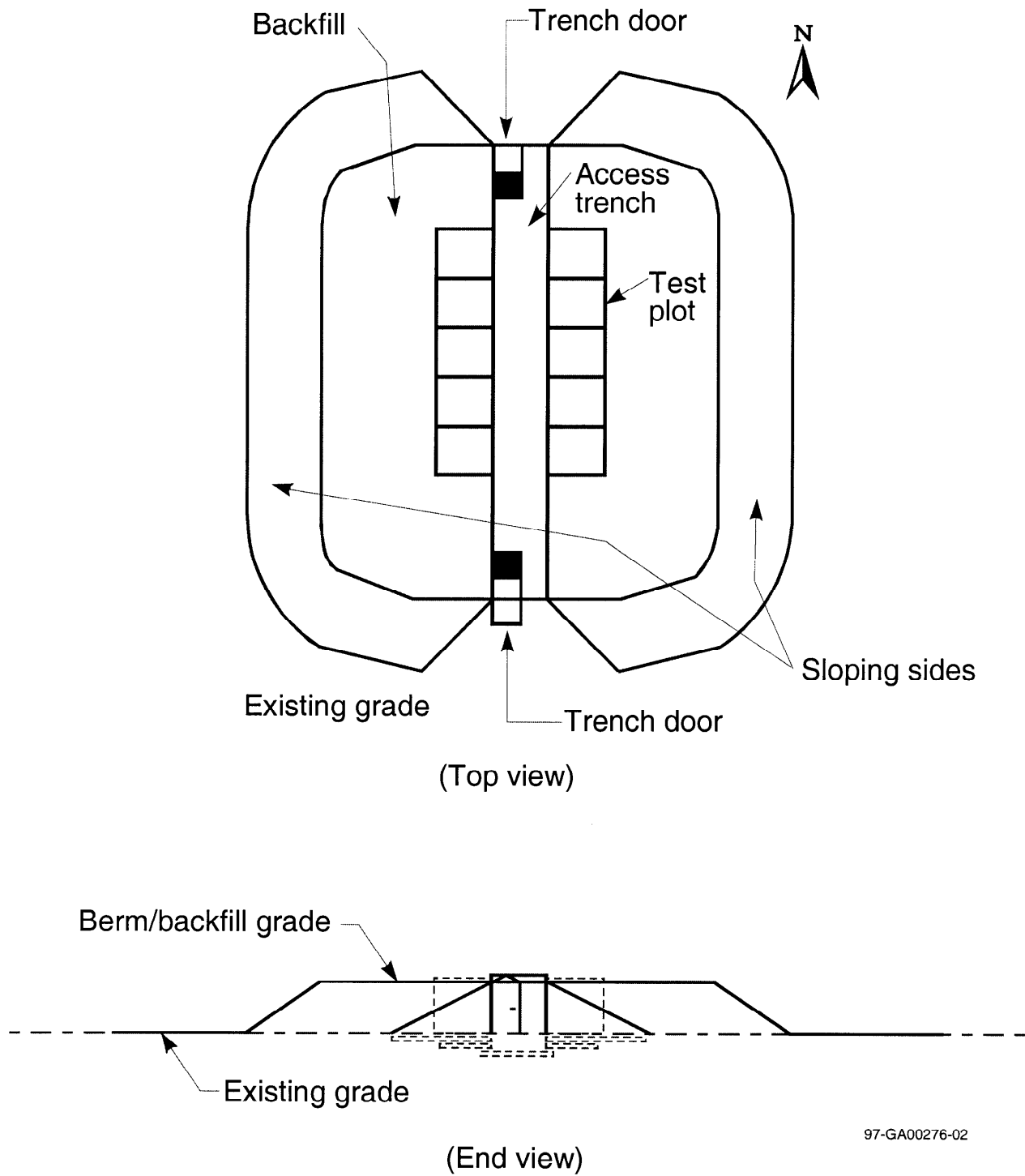
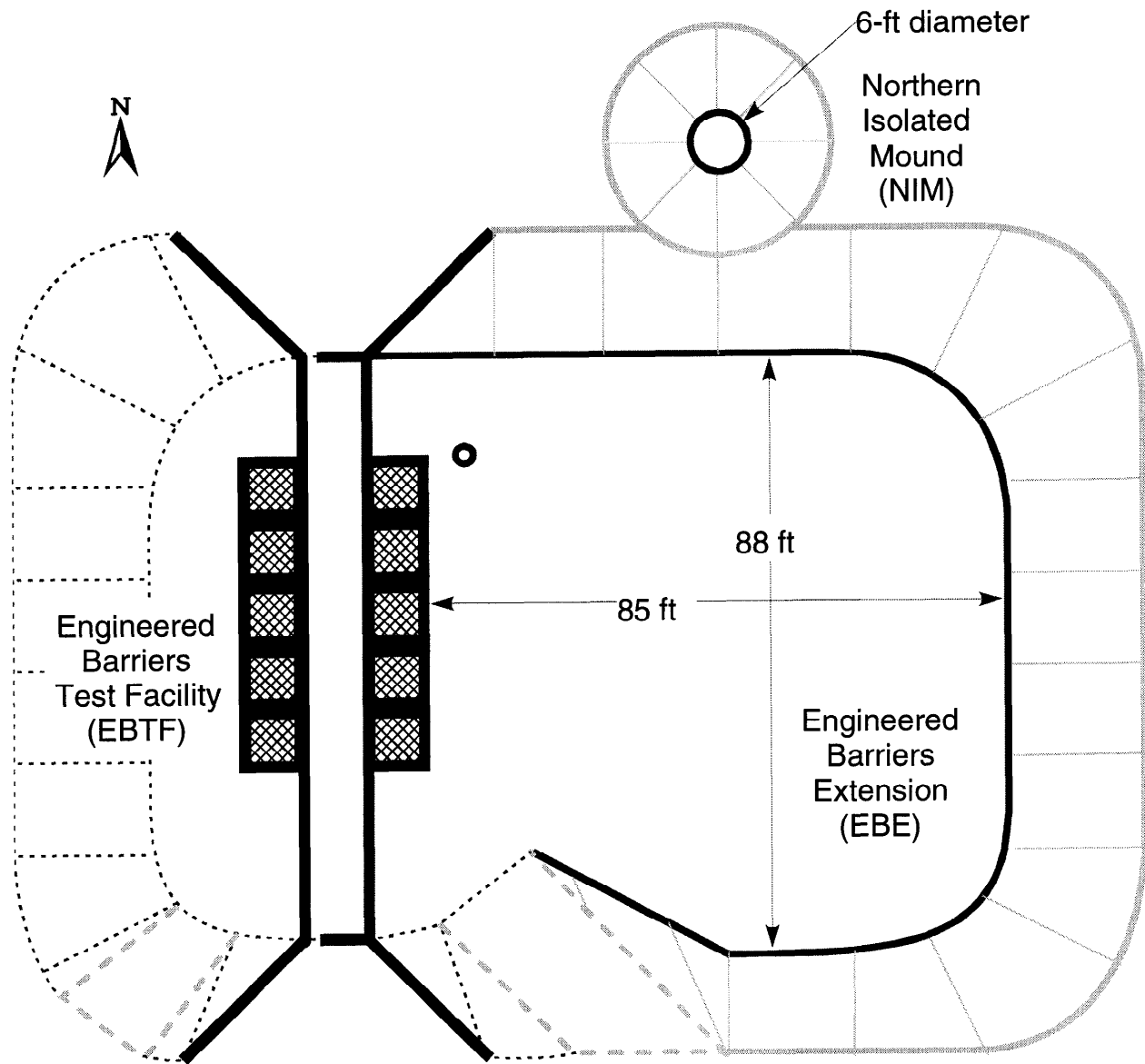


Figure 2. The Engineered Barriers Test Facility before the berm on the east side was extended for the corrosion test.



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Figure 3. Location and layout of the Engineered Barriers Extension and the Northern Isolation Mound, where the corrosion test is being conducted.

The configuration shown in Figure 4 arranges the coupon and probe placement locations in a grid within the berm, with spacing of 15-ft center to center. This arrangement separates the coupon arrays (edge to edge) by a minimum of 10 ft so that retrieval of any one array will not disturb the soil and corresponding soil characteristics (i.e., soil gas, soil moisture, and soil chemistry) in other test locations. (Note: different coupon arrays will be in place for different time periods.) The array placement locations were arranged to be at least 20 ft from the edge of the mound to minimize any edge effects. A setback of 10 ft from the existing EBTF (the facility adjacent to the mound) ensures a buffer zone.

The construction of the berm was completed in June 1997. The berm was constructed in accordance with Specification A-ECS 40902 (LMITCO 1996). Although specifications included compaction at more than 85% and soil moisture levels at 15 to 18%, initial moisture monitoring indicated soil moisture content levels at 20 to 25%.

1.7 Test Schedule

The coupon installation and retrieval schedule is shown in Table 1. The original schedule provided for corrosion measurements to be performed after 1, 2, 4, 8, 16, and 32 years. Reductions in funding for the program have impacted that schedule, such that the current schedule calls for corrosion measurements after 1, 3, 6, and 11 years, with out years yet to have programmatic funding identified.

Table 1. Coupon installation and retrieval schedule.

Coupon array	Depth (ft)	Installation date	Retrieval date	Berm Location (Figure 4)
CA01	4	Oct. 22, 1997	Oct. 23, 1998	I
CA02	10	Oct. 21, 1997	Nov. 3-5, 1998	
CA03	4	Oct. 22, 1997	October 15, 2000	II
CA04	10	Oct. 21, 1997	October 23, 2000	
CA05	4	Nov. 3, 1997	October 2003	III
CA06	10	Nov. 3, 1997	October 2003	
CA07	4	Oct. 22, 1997	October 2008	IV
CA08	10	Oct. 22, 1997	October 2008	
CA09	4	Nov. 10, 1998	October 2013	I
CA10	10	Nov. 11, 1998	October 2013	
CA11	4	October 26, 2000	October 2018	II
CA12	10	October 26, 2000	October 2018	
CA13	4	To be determined	To be determined	Mound

1.8 Document Organization

This report documents work-to-date related to the LTCD test project. Section 2 describes the direct test materials, coupon emplacement and removal process, coupon cleaning, and measurement methodology. Section 3 describes the results of the 3-year coupon retrieval and evaluation, including measurement results, corrosion rates, uncertainties, and evaluation of trends. Section 4 describes the monitored testing, equipment, and emplacement. Section 5 presents the available supporting data on soil moisture, microbial characterization, and chemical analysis of adhering soils for corrosion products. Section 6 discusses the present status of field monitoring. Section 7 presents conclusions and recommendations. References are listed in Section 8. Additional information about the LTCD test project is documented in the updated test plan (Adler-Flitton et al. 2001). Appendix A provides vertical scanning-interferometry measurements of select 3-year exposed metal coupons.